USE OF ROTATING SIDE-SCAN SONAR TO MEASURE BEDLOAD

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Abstract: Experiments in the 1960's demonstrated that the rate of sediment transport represented by migrating bedforms gives a more accurate measure of bedload transport than rates predicted from flow measurements. Rotating side-scan sonar can be used in the field to measure the rate of bedform migration and to calculate bedload transport rates. A rotating side-scan sonar system was deployed in the Colorado River in Grand Canyon for this purpose. For two sites where total load was measured using a depth-integrating sampler, approximately 5% and 0.3% of the sand transport was bedload involved in bedform migration; the other 95-99.7% occurred as suspended load that bypassed the bedforms.

INTRODUCTION

In deep marine flows and in rivers with soft, sandy beds, measurements of bedload transport are difficult to obtain using standard sampling techniques. Standard bedload samplers (such as Helley-Smith, BL-84, or BLH-84 samplers) tend to dig into sandy beds and thus can yield overly high measurements of bedload transport. This sampling problem illustrates the need to develop a method for measuring bedload transport that does not involve direct contact with the bed. One such method is to employ rotating side-scan sonar to measure the rate of bedload transport represented by migrating bedforms.

Simons et al. (1965) tested a variety of bedload transport equations using experimental flume data. They found that the rate of sediment transport represented by migrating bedforms gives a more accurate measure of bedload transport than rates predicted from flow measurements. The rate of sediment transport per unit width represented by a migrating bedform, called the "bedform transport rate" by Rubin and Hunter (1982), is equal to the product of three terms: bedform height, bedform migration speed, and a dimensionless shape factor (equal to 1/2 for bedforms whose cross-section approximates triangles touching end-to-end). These values can be measured relatively easily in the lab, but are difficult to measure in the field where bedforms are larger and the water is usually deeper and more opaque. The bedload transport rates calculated using this approach are mean rates for the area over which bedform heights and migration rates are sampled. In contrast, rates measured with a bedload sampler at a point on the bed are local rates, which can be expected to vary from approximately zero in a dune trough to twice the mean at a dune crest (Rubin and Hunter, 1982).

ROTATING SIDE-SCAN SONAR TECHNOLOGY

Hardware: Rotating side-scan sonar is well suited for field observations of bedform migration. It scans circular areas of the bed and has a range of tens of meters and a resolution of a few cm; it works in turbid water; and it can record sequential observations from a single point over time intervals of many hours. The first bed-deployed rotating sonar was an analog system that weighed several hundred pounds (Rubin et al., 1983). Modern commercially available systems are digital and weigh just a few pounds.

The system that we tested operates at 675 kHz and records up to 2000 acoustic pixels per acoustic ping. The transducer is mounted approximately 1 m above the bed. At a range of 10 m, it records 1000 pixels per ping (1 per cm) and takes 1-2 minutes to complete each circular scan. A typical deployment recorded several hundred complete scans over a duration of 10-20 hours.

Data processing: Sequential images at a site were converted into digital movies and displayed frame by frame on a computer screen. Individual dunes were tracked, and their migration speeds determined from the observed migration distances and times. Dune height was determined from fathometer profiles collected when the rotating side-scan sonar was deployed or by calculations from dune wavelength and assuming a height/wavelength ratio of 1/15. A preferable option would be to use a rotating interferometric or multibeam system to record 3-dimensional topography, rather than the 2-dimensional planform images recorded by standard rotating side-scan sonar.

EXAMPLE

The rotating side-scan sonar was deployed at approximately 20 locations in the Colorado River in Grand Canyon. Figure 1. shows two images and bedform-migration vectors at one of these sites.

A.

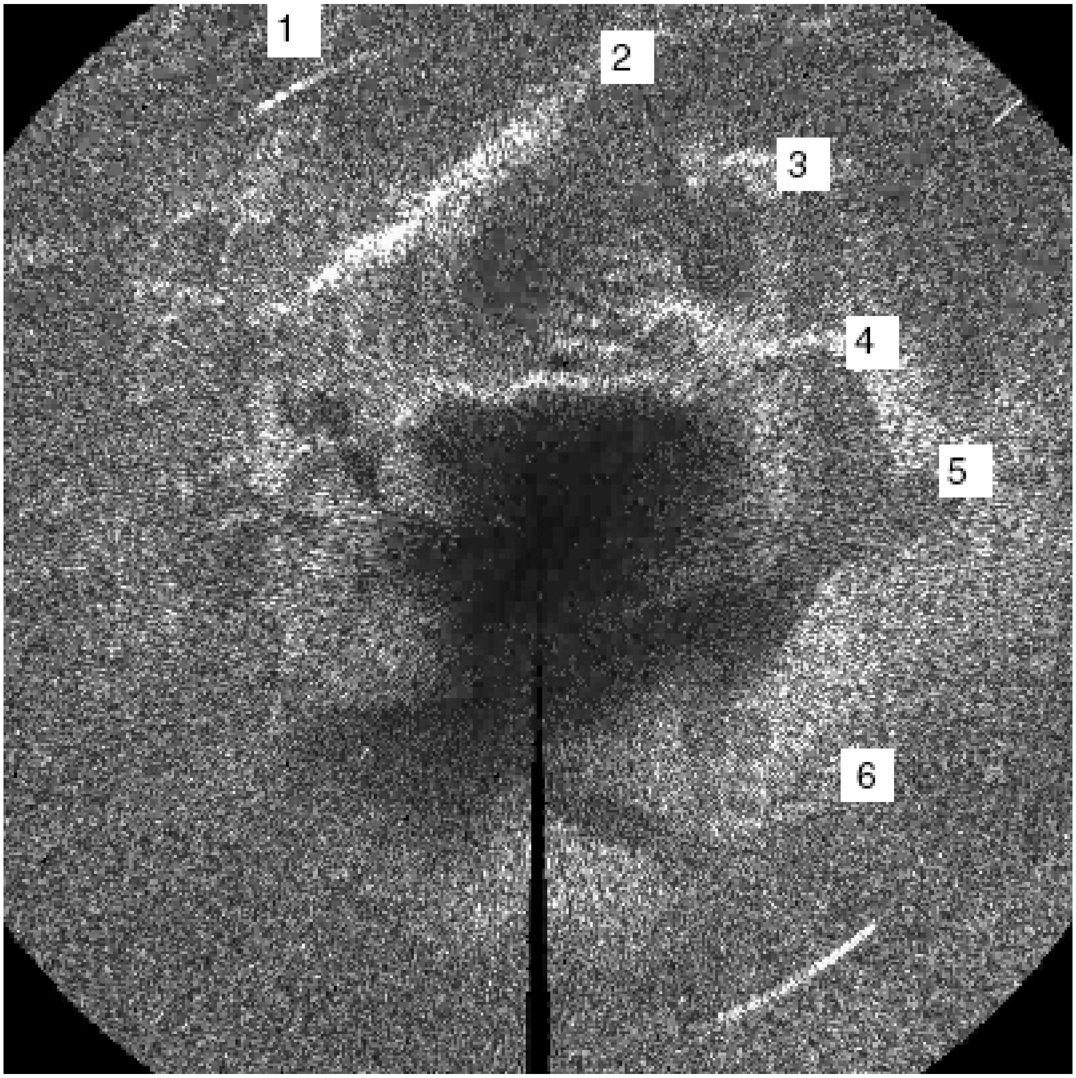
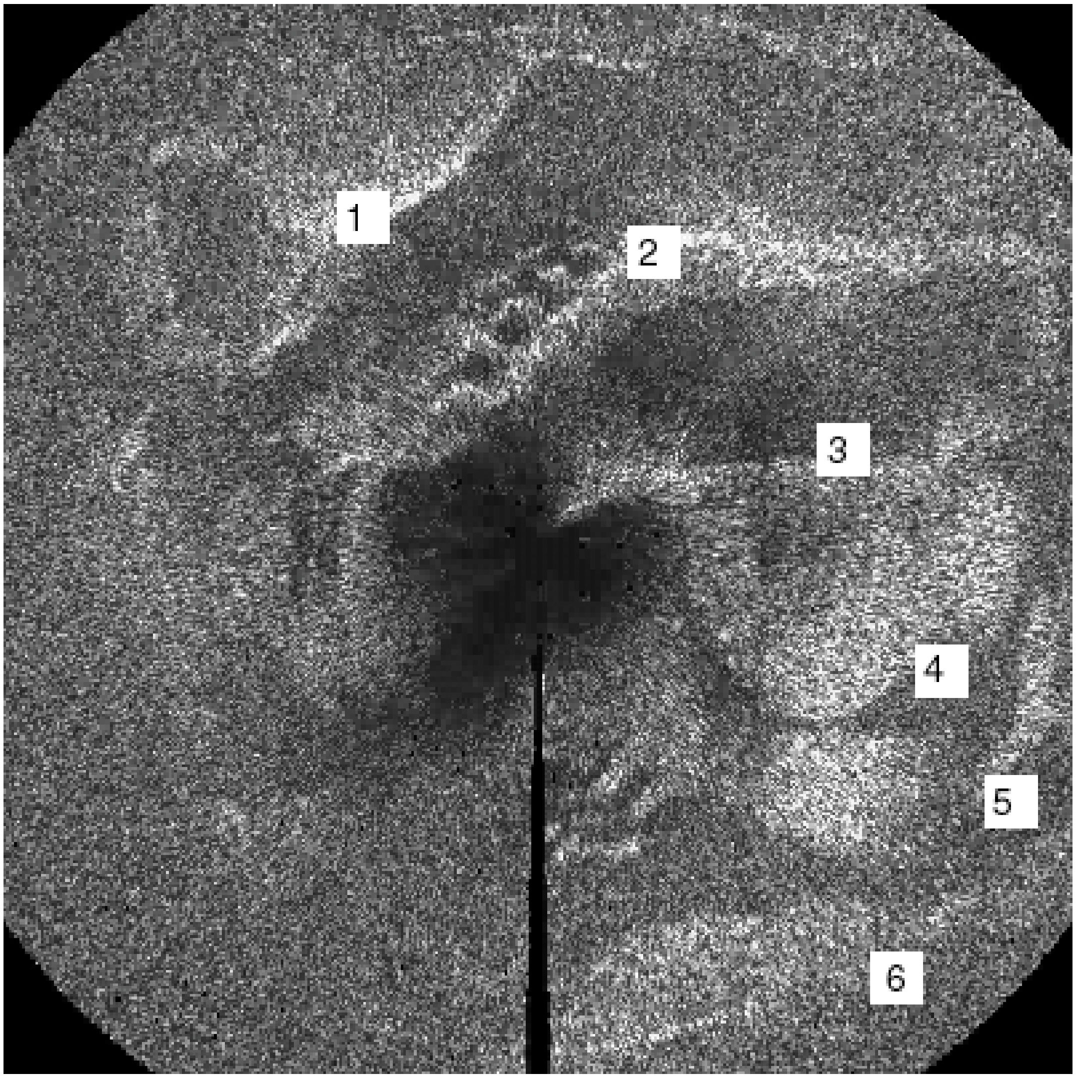
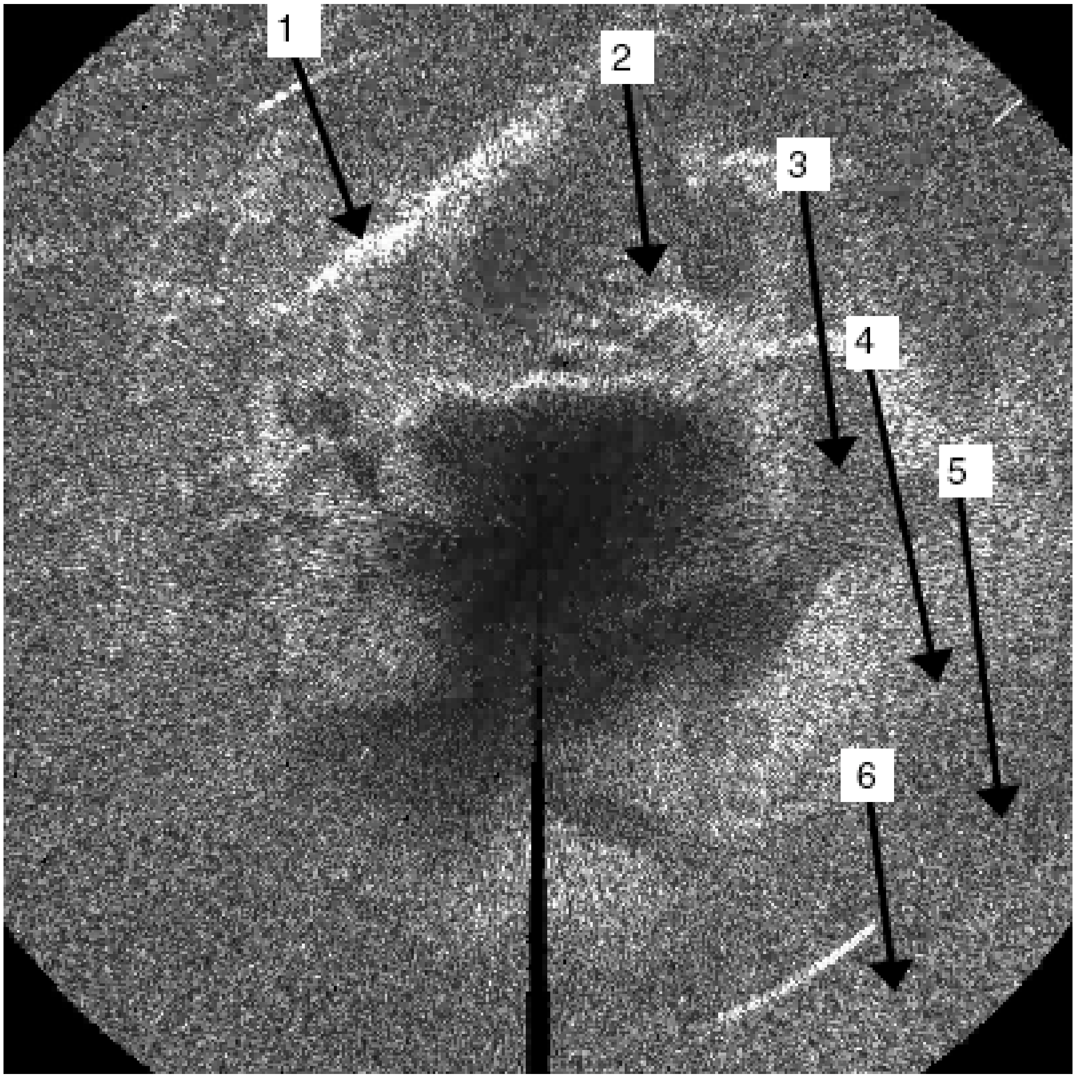


Figure 1. Rotating sonar images from the Colorado River at the Grand Canyon gage cableway. Flow is approximately from top of the image to the bottom. Bright areas on the image are strong acoustic reflections, indicating slopes that are facing toward the centrally located sonar transducer. The diameter of the circular part of the image is 20 m. Numbers identify 6 specific locations on 6 dunes. **A**. Image at initial time of bedform migration measurements. **B**. Same area of river bed after 2.5 hours of dune migration. **C**. Initial image with dune migration vectors superimposed. To track individual dunes requires viewing the intervening frames. The mean dune migration distance during the observation period was 2 m, and the migration speed was 0.02 cm/s.

B.



C.



APPLICATION OF THE METHOD

Comparison of bedload and suspended-load transport: To determine the relative importance of bedload and suspended-load transport in the Colorado River in Grand Canyon, measurements of suspended load were made at 2 locations using a P-61 point-integrating sampler during the interval of rotating side-scan sonar observations. These measurement locations were at 2 USGS gaging stations: (1) the Colorado River above Little Colorado River near Desert View (station # 09383100) and the Colorado River near Grand Canyon (station # 09402500). These gages are informally known as the Lower Marble Canyon gage and Grand Canyon gage, respectively. The discharge of water and the grain size of the bed sand at each location were comparable during the measurements. At the Lower Marble Canyon gage, the discharge of water during the measurement period was approximately 550 m^3/s [19,300 cfs] and the median size of the bed sand was 0.45 mm (as measured with a pipe dredge). At the Grand Canyon gage, the discharge of water during the measurement period was approximately 595 m^3/s [20,800 cfs] and the median size of the bed sand was 0.42 mm. At the Lower Marble Canyon gage, bedload involved in bedform migration was only 0.3% of the total sand load; at the Grand Canyon gage, bedload was approximately 5% of the total sand load.

Other observations: In addition to allowing accurate measurements of bedload transport, rotating side-scan sonar provides information about dune orientation relative to flow; cross-channel differences or similarities in transport rate; cross-channel differences in bedform size, migration speed, and migration direction; migration of superimposed dunes over larger bedforms; changes through time in bedforms and sediment transport; and bedform interactions such as splitting and merging. Rotating sonar is also useful in detecting starved bedforms migrating over a cobble bed: individual cobbles appear and disappear as they are exposed and then buried by troughs and crests of the migrating dunes.

REFERENCES

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